



UNIVERSITY OF CALIFORNIA *Berkeley*  
**Transportation Sustainability**  
RESEARCH CENTER

# Drivers of Change: Taking Us in A New Direction



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April 20, 2018





# Overview

- Topics impacting future of mobility
- Overarching trends highlights
- Shared mobility and automated vehicles
- Transportation technologies
- Statewide systems
- Data, pilots, scenarios, and equity
- Concluding thoughts



## FUTURE OF MOBILITY WHITE PAPER



# Topics Impacting California's Transportation Future

UC Berkeley's Transportation Sustainability Research Center reviewed developments and market predictions for the following topics in the **Caltrans' Future of Mobility White Paper**.

## Shared Mobility

- Bikesharing
- Carsharing
- Ridesourcing/Transportation Network Companies (TNCs)
- Alternative Transit Services
- Shared Mobility Public-Private Partnerships and Data Sharing

## Overarching Trends

- Climate Change and Sustainability
- Demographics
- Economics
- Transportation Equity and Public Health

## Transportation Technology

- Connected and Automated Vehicles
- Zero Emission Vehicles
- Information and Communications Technology
- Cybersecurity Risk
- 3D Printing
- Blockchain
- Drones and Unmanned Aerial Vehicles (UAVs)
- On-demand Trucking/"Uber for Freight"
- Hyperloop

## Statewide Systems

- Freight and Goods Movement
- California's Passenger Rail System

The **current state of knowledge** about these topics, and how they will affect California's transportation system through 2050, **varies greatly**.

# Caltrans Future of Mobility White Paper Topics

## Statewide Systems

- Freight and Goods Movement (14)
- California's Passenger Rail System (15)

## Shared Mobility

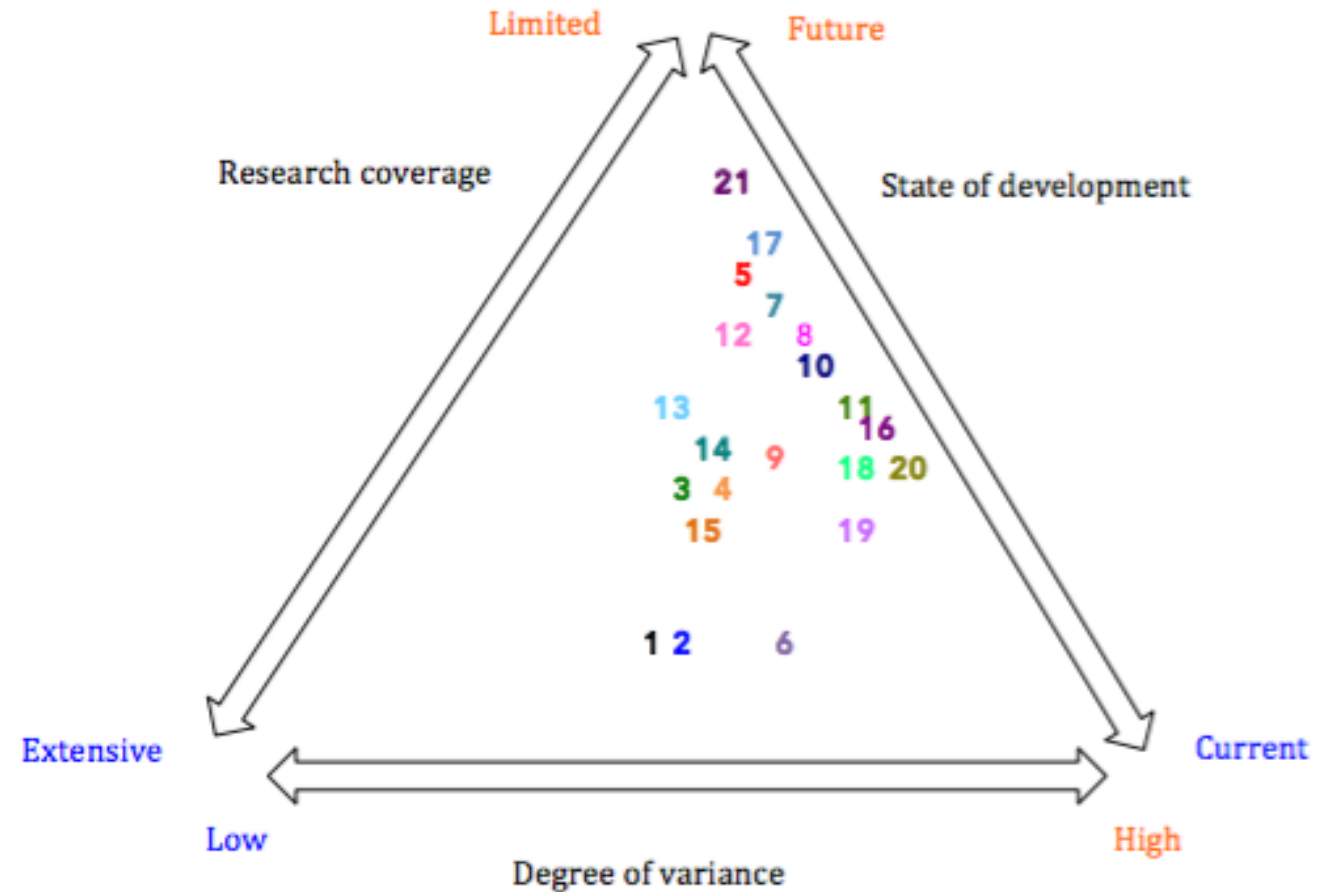
- Bikesharing (8)
- Carsharing (7)
- Ridesourcing/TNCs (9)
- Alternative Transit Services (11)
- Shared Mobility Public-Private Partnerships and Data Sharing (12)

## Transportation Technology

- Connected and Automated Vehicles (5)
- Zero Emission Vehicles (6)
- Information and Communications Technology (13)
- Cybersecurity Risk (16)
- 3D Printing (18)
- Blockchain (17)
- Drones and Unmanned Aerial Vehicles (UAVs) (19)
- On-demand Trucking/"Uber for Freight" (20)
- Hyperloop (21)

## Overarching Trends

- Climate Change and Sustainability (3)
- Demographics (1)
- Economics (2)
- Transportation Equity and Public Health (4)

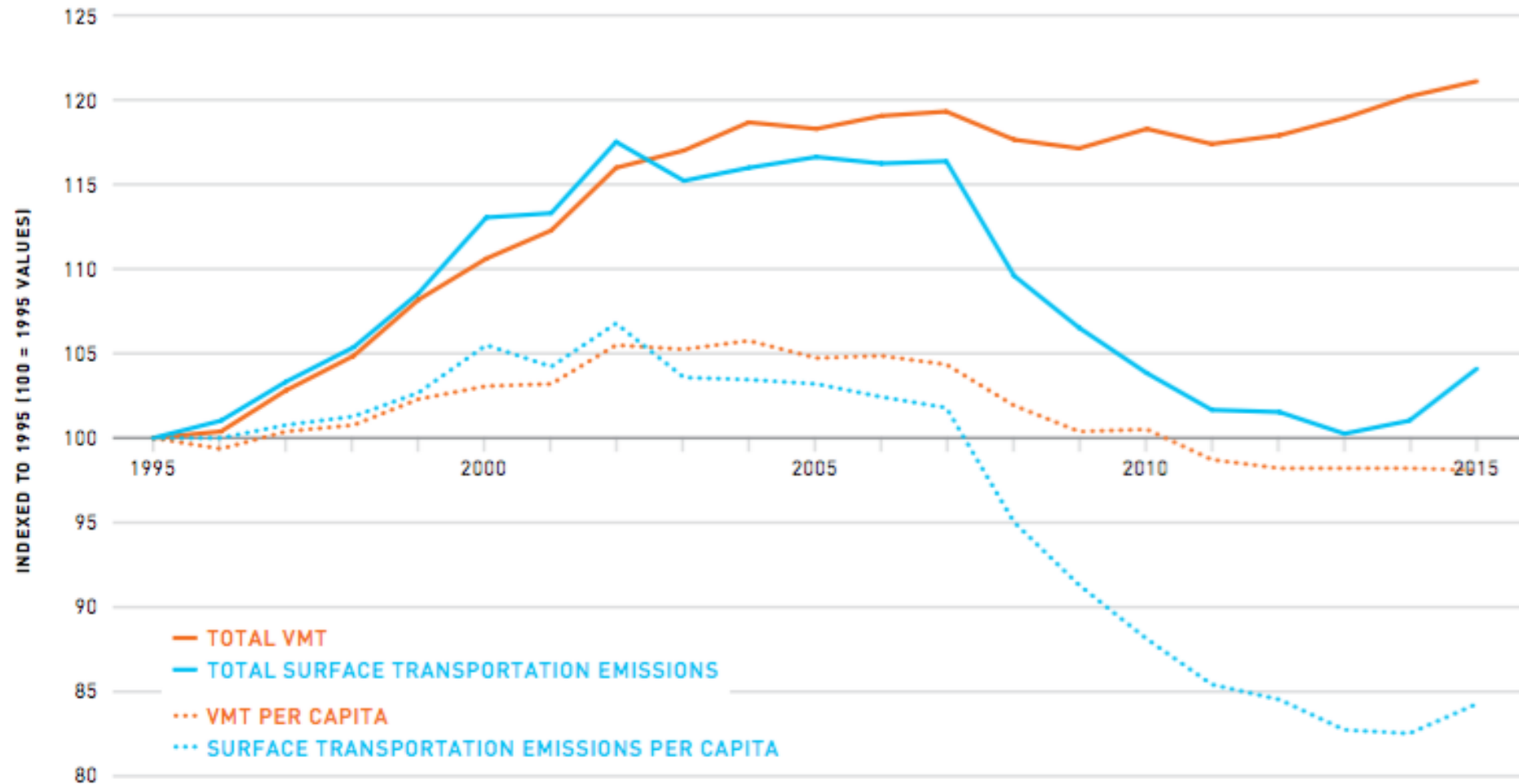


# Highlights from Overarching Trends

Demographics	Economics	Transportation Equity and Public Health
<ul style="list-style-type: none"><li>California is projected to <b>grow from 39.4 million to 51.1 million, at 0.6 percent per year on average</b>, between 2016 and 2060</li><li>Central Valley, San Francisco Bay Area, Inland Empire, and greater Sacramento <b>regions growing at a greater rate</b> than the statewide average</li><li>Predictions of Generation Z and Baby Boomer changes in travel behavior are scarce</li></ul>	<ul style="list-style-type: none"><li>Between 2016 and 2021, <b>California total employment is expected to increase one percent per year on average</b></li><li>Per capita <b>income is projected to rise</b> by an average of 1.8 percent per year</li><li>It is unclear whether telecommuting and online shopping will contribute to an overall increase or decrease of vehicle miles traveled (VMT)</li></ul>	<ul style="list-style-type: none"><li>Five of California's <b>smoggiest cities are also locations with the highest projections of ozone increases</b> associated with climate change</li><li><b>34 percent of urban U.S. African Americans and 27 percent of Hispanics report taking public transit daily, almost daily, or weekly, compared to 14 percent of whites</b></li></ul>

# Highlights from Overarching Trends (Cont'd)

## California VMT and GHG Emissions from Surface Transportation



Source: Next 10, 2017



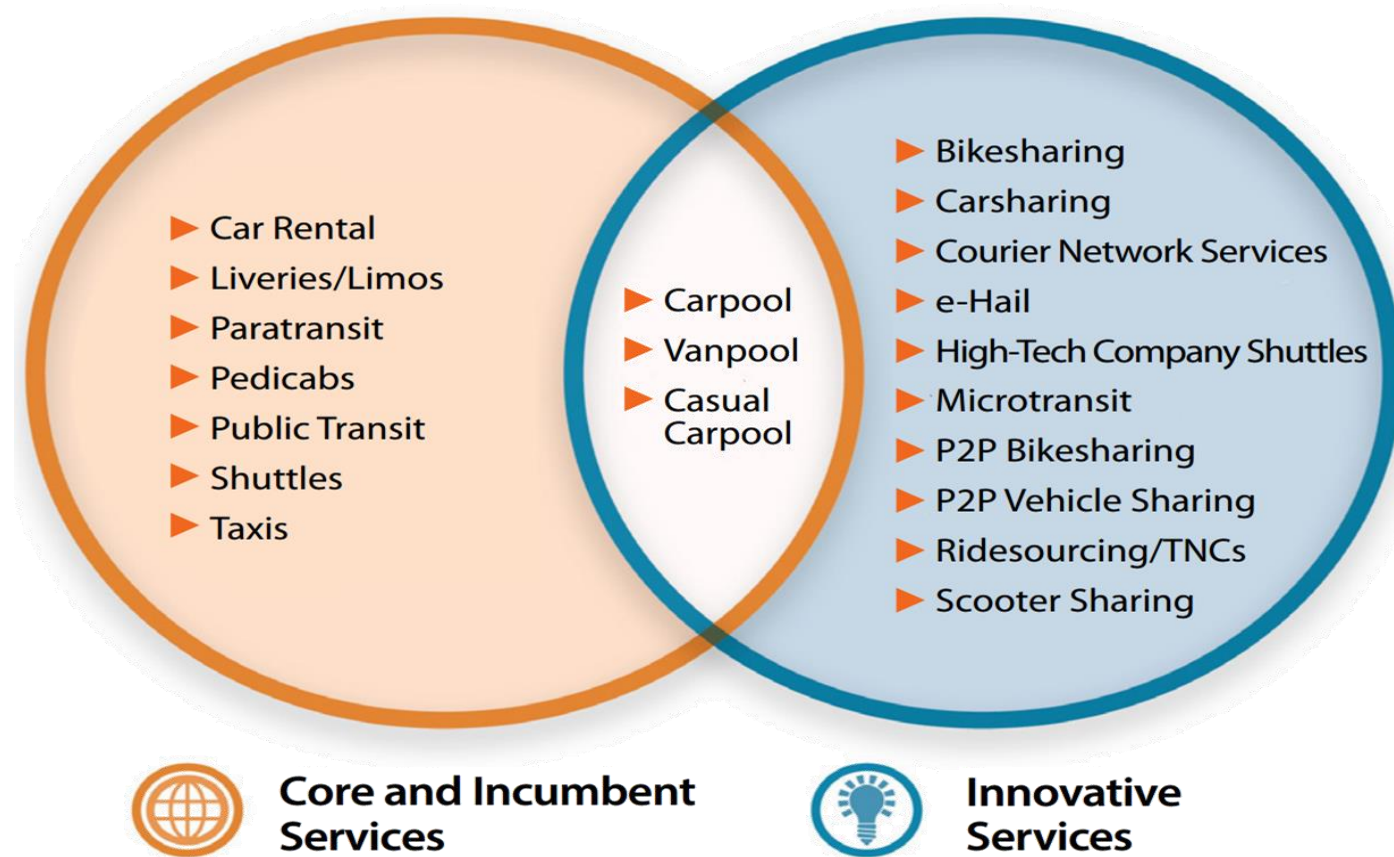
# Shared Mobility: It's Not New





# Defining Shared Mobility

Shared mobility—the shared use of a vehicle, bicycle, or other low-speed travel mode—is an innovative transportation strategy that enables users to have short-term access to a mode of transportation on an as-needed basis.



# Shared Mobility Impacts



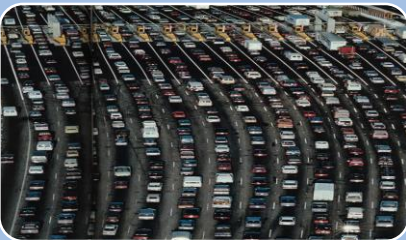
## Environmental Effects

- Can yield lower GHG emissions via decreased VMT, low-emission vehicles, carbon offset programs
- Can reduce vehicle ownership



## Social Effects

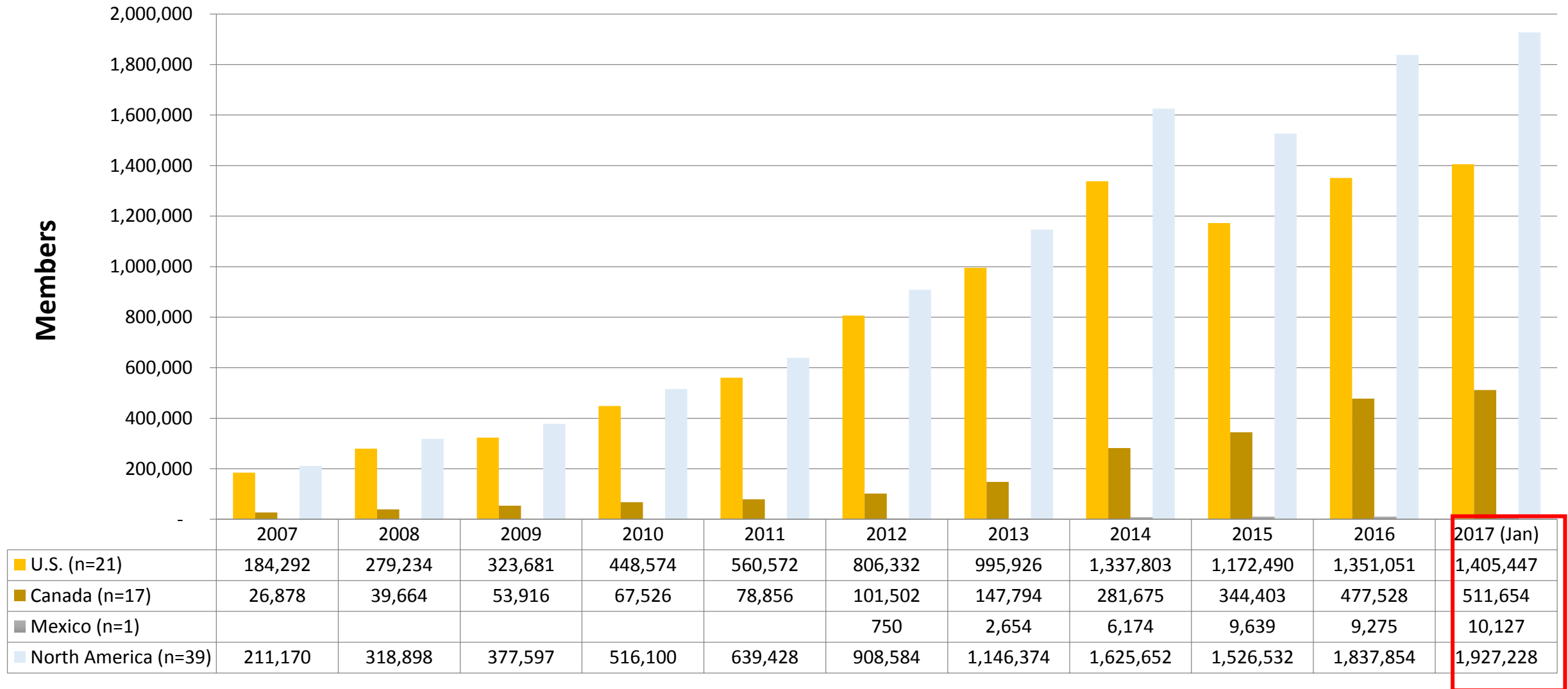
- Offers “pay-as-you-go” alternative to vehicle ownership
- Reasonable for college students and low-income households
- Can increase mobility of low-income residents, disabled, and college students
- Provides car use without bearing full ownership cost



## Transportation Network Effects

- Takes cars off the road via reduced VMT, forgone/delayed vehicle purchases or sale of vehicle
- Reduced parking demand
- Can complement/complete with alternative transportation modes, e.g., public transit, walking, biking, etc. , and can help address first and last mile issue

# North American Carsharing Membership Growth





# Recent Study of One-Way Carsharing

## Methodology:

- Online survey from ~9,500 North American car2go members residing in Calgary; San Diego; Seattle; Vancouver; and Washington, D.C.
- Activity data analysis

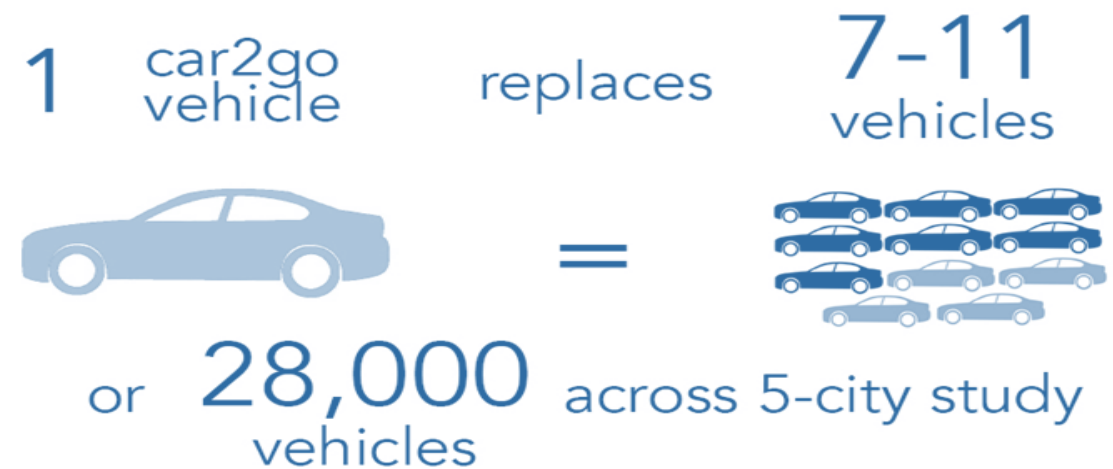


# Recent Study of One-Way Carsharing

## ONE-WAY CARSHARING IMPACTS

### Member Vehicle Holdings

2% - 5%	sold a vehicle
1 - 3	vehicles sold per car2go vehicle
7% - 10%	postponed a vehicle purchase
4 - 9	vehicle acquisitions suppressed per car2go vehicle



### Reduction of VMT and GHG emissions



6% - 16%

Average reduction of VMT per car2go household



4% - 18%

Average reduction of GHG emissions per car2go household

# One-Way Impacts: North America



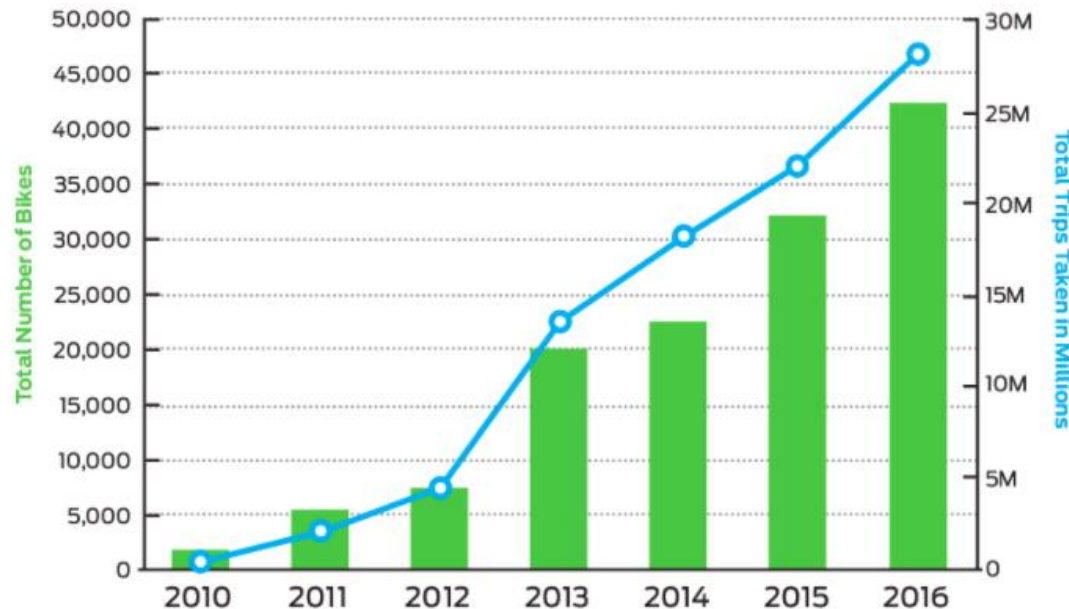
City	Vehicles Sold	Vehicles Suppressed (foregone purchases)	Total Vehicles Removed per Carsharing Vehicle	Range of Vehicles Removed per Carsharing Vehicle	% Reduction in VMT by Car2go Hhd	% Reduction in GHGs by Car2go Hhd
Calgary, AB (n=1,498)	2	9	11	2 to 11	-6%	-4%
San Diego, CA (n=824)	1	6	7	1 to 7	-7%	-6%
Seattle, WA (n=2,887)	3	7	10	3 to 10	-10%	-10%
Vancouver, BC (n=1,010)	2	7	9	2 to 9	-16%	-15%
Washington, D.C. (n=1,127)	3	5	8	3 to 8	-16%	-18%



# Bikesharing Impacts to Date

Projections from 2015 predict that the bikesharing market could grow to \$6.3 billion by 2020.  
As of 2016, 28 million rides were taken with bikesharing services across the U.S.

**Bikesharing Growth in the U.S., 2010 – 2016**



Source: NACTO, 2017

## Impacts to Date:

- In denser urban areas, bikesharing use is correlated with reduced rail use
- In smaller cities, bikesharing is correlated with increased rail use
- Bikesharing trips can substitute for public transit and walking trips for non-members
- 15 to 20 percent of bikesharing users decreased car use, per one study

# Ridesourcing/TNC: Modal Shift Impacts

Study Authors Location Survey Year  Mode	Rayle et al.* San Francisco, CA 2014	Henao* Denver and Boulder, CO 2016	Gehrke et al.* Boston, MA 2017	Clewlow and Mishra** Seven U.S. Cities***** Two Phases, 2014 – 2016	Feigon and Murphy*** Seven U.S. Cities***** 2016	Hampshire et al.**** Austin, TX 2016
Drive (%)	7	33	18	39	34	45
Public Transit (%)	30	22	42	15	14	3
Taxi (%)	36	10	23	1	8	2
Bike or Walk (%)	9	12	12	23	17	2
Would not have made trip (%)	8	12	5	22	1	-
Carsharing / Car Rental (%)	-	4	-	-	24	4
Other / Other ridesourcing (%)	10	7	-	-	-	42 (another TNC) 2 (other)

Note: Mode replacement findings of these studies employ various methodologies, depending on survey instrument used and analysis methods chosen. Different methodologies can have a notable impact on findings.



# Ridesourcing/TNC Impacts on VMT

- **3.5% increase in citywide VMT** and 7% increase in Manhattan, western Queens, and western Brooklyn in 2016 (Schaller, 2017)
- **In Denver, average of 100 vehicle miles to transport passenger 60.8 miles (~40% deadheading miles)** (Henao, 2017)
- **In SF, SFCTA (2017) found ~20% of total ridesourcing VMT included deadheading miles**
- **May be increase in VMT due to ridesourcing**, although exact magnitude still unknown and likely varies by location (e.g., density, land use, and built environment)
- Services still new (August 2012) and evolving (e.g., pooling, SAVs)



# Alternative Transit Services



Service Name	Route Type	Service Description	Fare Range
Chariot	Fixed route	15-seater vans operate on predetermined routes, but users can request additional stops	\$3 to \$6/ride Accepts pre-tax commuter benefits
Via	Flexible routes and scheduling	Users request rides in real time, and they are picked up by a Via van in minutes	\$5 to \$7/ride Accepts pre-tax commuter benefits

- Microtransit (on-demand transit) may increase or decrease public transit ridership
- Paratransit partnerships have decreased user wait times and increased paratransit service use in some recent pilot projects
  - Partnerships can decrease subsidy costs for rides

# Shared Mobility User Demographics: Summary

Mode	Race/Ethnicity	Income	Educational Attainment	Age
Roundtrip Carsharing (N. America)		21% earned >\$100K 23% earned <\$40K	81% had a 4-year degree or higher	35% ages under 30 31% Ages 30-40
One-Way Carsharing (N. America)	80-87% Caucasian 1-10% Hispanic/Latino 1-5% African American	35-56% earned >\$100K 7-17% earned <\$35K (US)	72-96% had a 4-year degree or higher (across 5 cities)	48-64% ages under 35 32-41% ages 35-54
P2P Carsharing (N. America)	67% Caucasian 3% Hispanic/Latino 3% African American	30% earned >\$100K 21% earned <\$35K (US)	86% had a 4-year degree or higher	73% ages under 35 23% ages 35-54
Station-Based (Docked) Bikes sharing (N. America Multi-City Studies)	74-92% Caucasian 1-5% Hispanic/Latino 1-2% African American	29-39% earned >\$100K 9-26% earned <\$35K	55-89% had a 4-year degree or higher (2 studies)	37-54% ages under 35 36-51% ages 35-54
Ridesourcing/TNCs (SF Bay Area)		38% earned >\$100K 9% earned <\$30K	81% had a 4-year degree or higher	73% ages under 35 25% ages 35-54
Microtransit (Kansas City)	89% Caucasian 6% African American 6% Asian American	50% earned >\$100K 6% earned <\$35K	100% had a 4-year degree or higher	55% ages under 35 39% ages 35-54

# Shared Mobility Impacts on Public Transportation: Summary

Mode	Decrease/Increase	Public Transit Impacts
Roundtrip Carsharing (N. America)	Net decrease (-)	For every 5 members that use rail less, 4 ride it more; For every 10 members that use the bus less, 9 ride it more.
One-Way Carsharing (N. America)	Net decrease, although an exception in Seattle (- / +)	In Seattle, where a small percentage of respondents increase their use exceeding the smaller percentage of respondents decreasing their rail use. Across the other four cities, more people report a decrease in their frequency of urban rail and bus use than an increase.
P2P Carsharing (N. America)	Net decrease (-)	Those increasing and decreasing their bus and rail use were closely balanced in number, with 9% increasing bus and 10% decreasing use. Similar effects were found with rail, as 7% reported increasing rail use, while 8% reported decreasing it.
Station-Based (Docked) Bikesharing (N. America Multi-City Studies)	Net increases in bus/rail in small- and medium-sized cities Small net decreases in bus/rail in larger cities (+ / -)	-Small net increases in bus and rail use in small- and medium-size cities (e.g., Minneapolis) -Small net decreases in bus and rail use in larger cities (e.g., Mexico City)
Pooling (Casual Carpooling in Bay Area)	Net decrease (-)	Majority of casual carpoolers were public transit users. In the Bay Area, 75% were casual carpoolers.
Ridesourcing/TNCs (SF Bay Area)	Net decrease (-)	33% competition with public transit, 4% first mile and last mile (destination or origin is public transit stop)

# Relationship Between Shared Mobility & Public Transit



**First-and-Last Mile Connections**



**Public Transit Enhancement & Replacement**



**Late-Night Transportation**

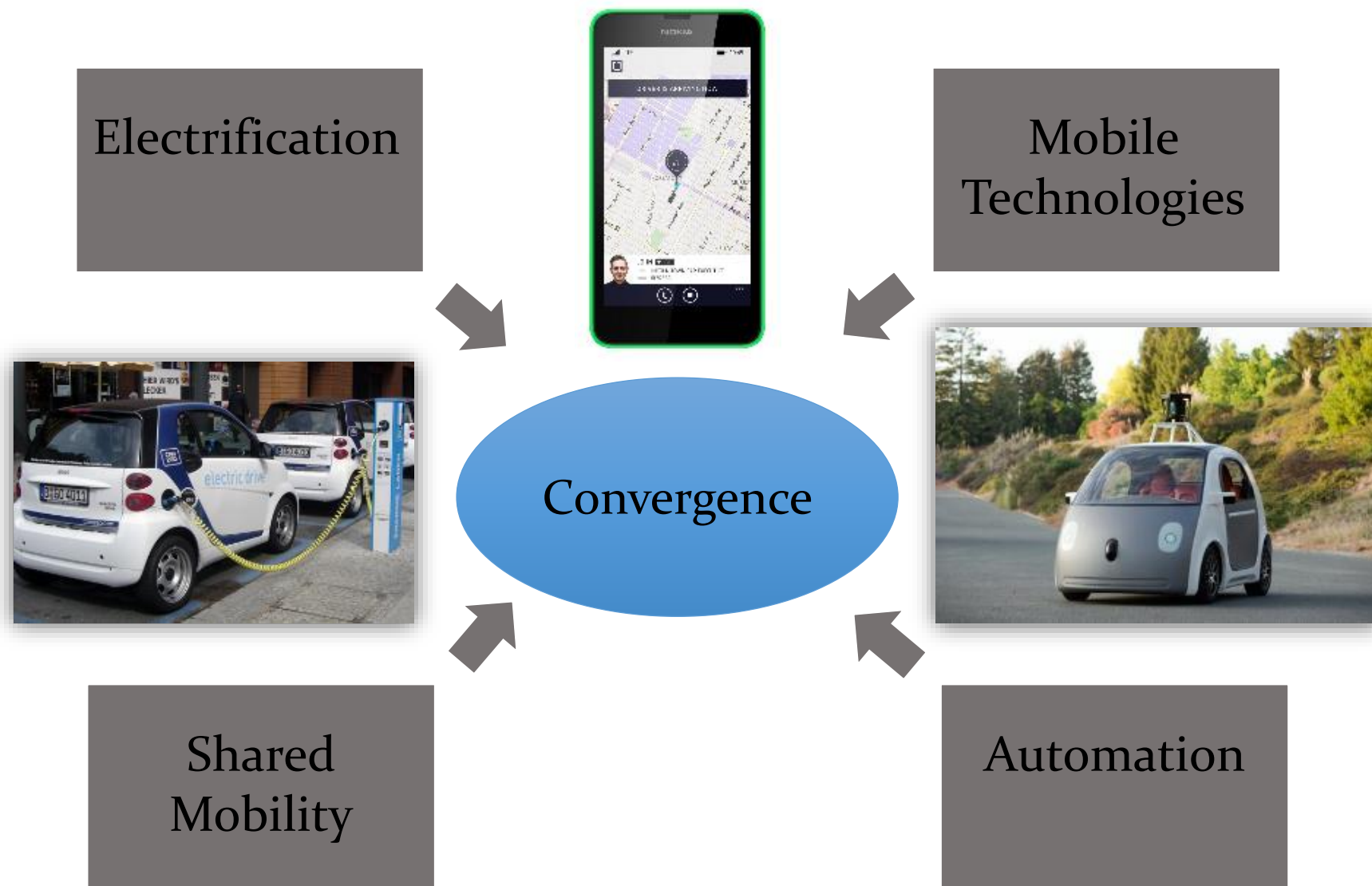


**Paratransit**

**Others...**



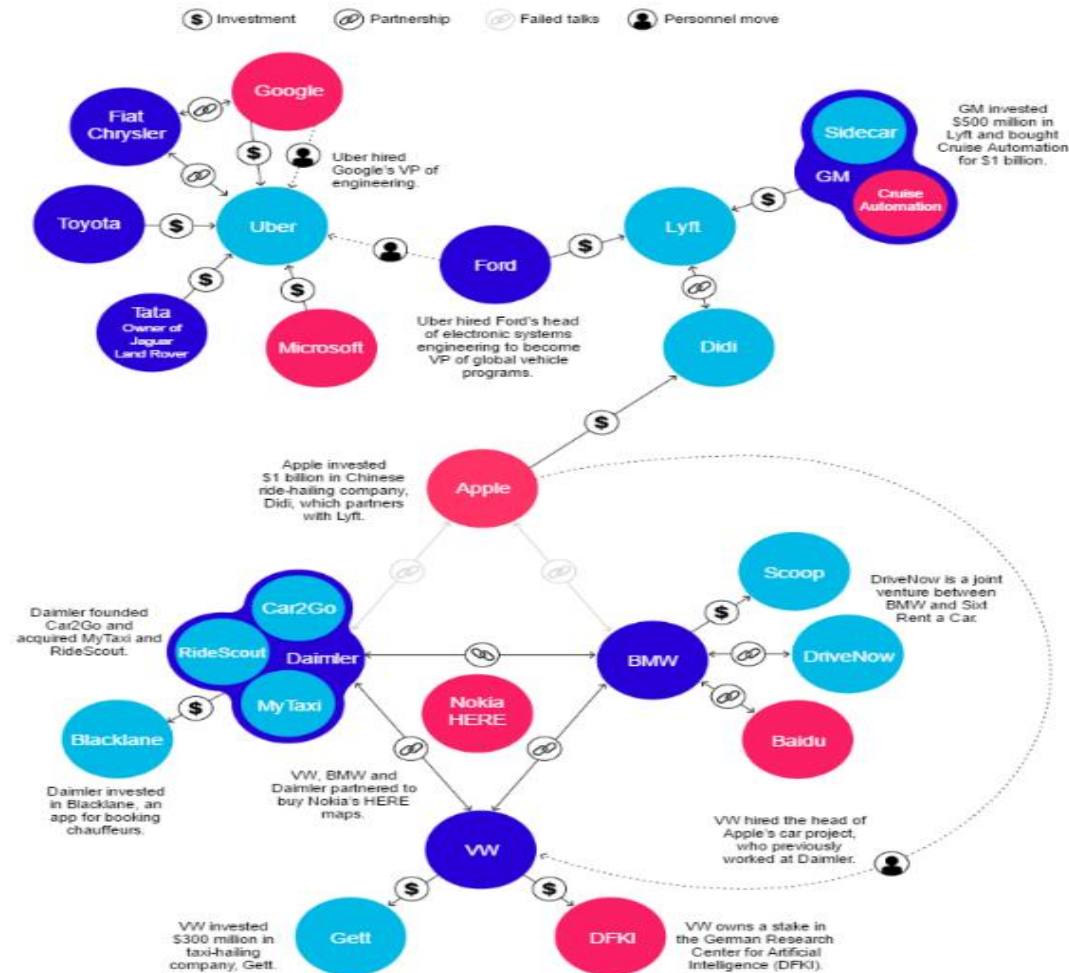
# SECA





# Shared Automated Vehicles (SAVs)

50 companies (and growing) in CA registered to test AVs



# SAV Developments – Conventional Vehicle SAVs

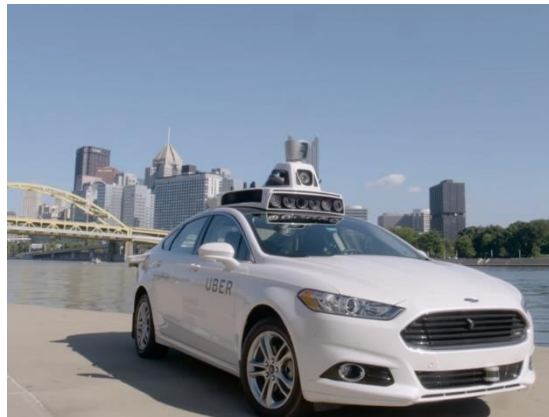
All SAV pilots with conventional vehicles to date have a steering wheel in the vehicle and an engineer in the driver's seat for safety

**Waymo**



**Example Pilot:**  
Early Rider Program,  
Phoenix, AZ

**Uber**



**Example Pilot:**  
Pittsburgh, PA

**NuTonomy**



**Example Pilot:**  
One North, Singapore

# SAV Developments – Conventional Vehicle SAVs

## Waymo Early Rider Program, Phoenix, AZ



- Alphabet's Waymo launched its Early Rider program in April 2017, inviting residents of certain areas of Phoenix, Arizona to ride in their autonomous vehicles
- After a trial period in Phoenix, Waymo plans to expand its fleet from 100 to 600 autonomous Fiat-Chrysler Pacifica Hybrid minivans



# SAV Developments – Conventional Vehicle SAVs

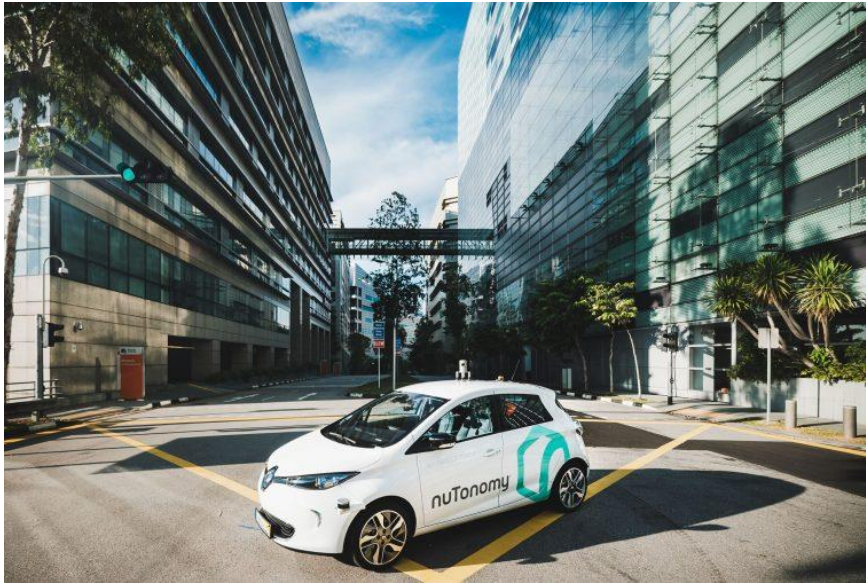
Uber, Pittsburgh, PA



- In September 2016, Uber began a pilot in Pittsburgh, PA serving around 1,000 select Uber customers with four autonomous Ford Fusions
- There is a backup driver and engineer present in the front seats

# SAV Developments – Conventional Vehicle SAVs

NuTonomy, One North Business Park, Singapore



- In August 2016, NuTonomy launched a public trial of their autonomous vehicles in a 1.5 square-mile section of Singapore, called One North
- NuTonomy partnered with Grab, the Southeast Asia-based ridesourcing company, and vehicles can be hailed via smartphone through Grab's platform



# SAV Developments – Planned SAV Pilots

## Low-Speed SAV Shuttle Pilots

*EasyMile, Treasure Island,  
San Francisco Bay Area, CA*



- EasyMile and the San Francisco County Transportation Authority are planning a pilot to serve first and last mile public transit trips on Treasure Island by 2020

*Local Motors Olli, Miami  
Dade County, FL and Las  
Vegas, NV*



- Local Motors' Olli has been tested in National Harbor, MD and has expansion plans to serve passengers in Miami and Las Vegas

# SAV Developments – Planned SAV Pilots

## Conventional Vehicle SAV Pilots

*NuTonomy and Lyft, Boston, MA*



- NuTonomy has been testing its AVs in the Seaport and Fort Point areas of Boston since April 2017
- In June 2017, Lyft and NuTonomy formed a partnership with plans to deploy a SAV pilot serving passengers sometime in the coming months

*Delphi and Transdev, Normandy and Paris, France*

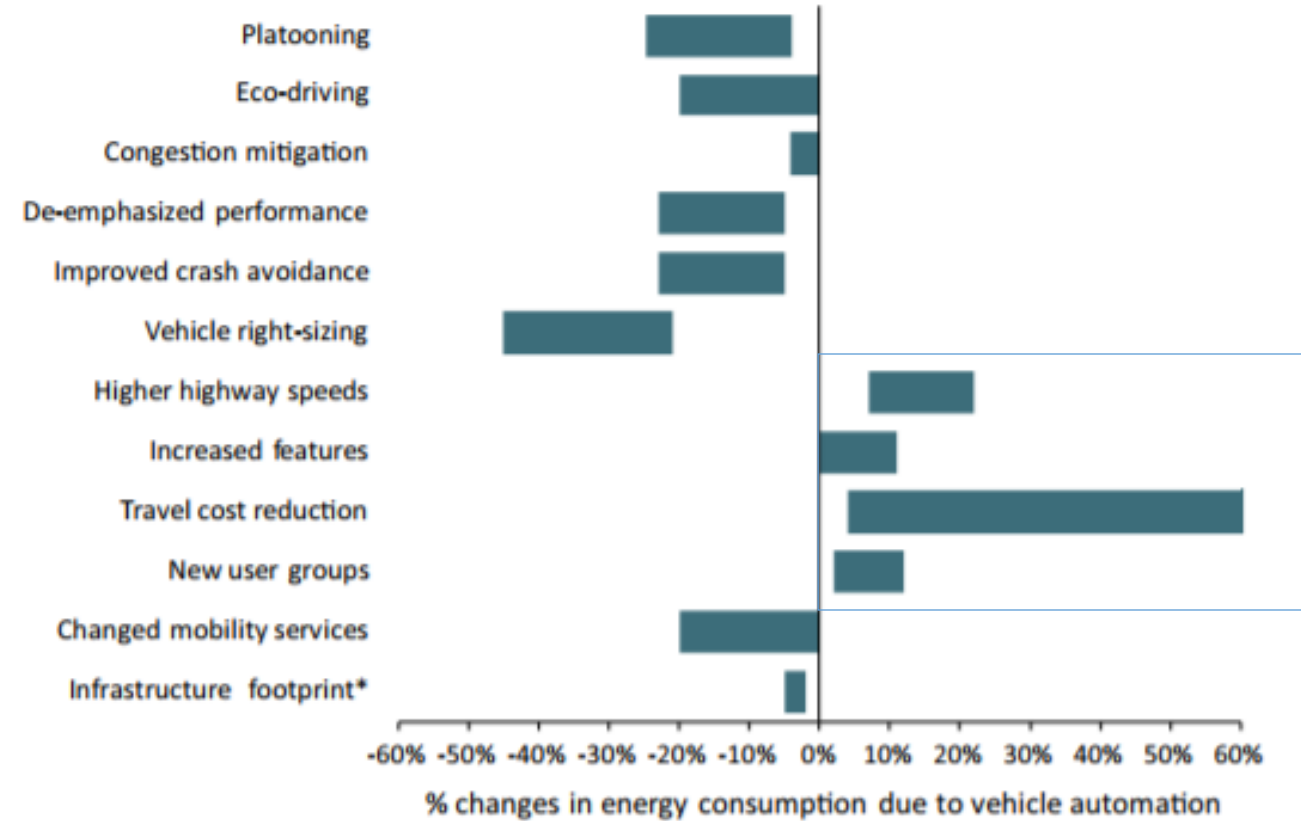


- In June 2017, Delphi and Transdev announced that they will test AVs in Normandy and outside Paris in advance of building a commercial service starting in 2019, which could be deployed in other markets, including North America

# SECA Potential Challenges

- Higher upfront vehicle costs
- Increased VMT (due to lower costs, increased use, modal shift away from public transit, longer commutes, roaming AVs, etc.)
- More convenient and productive travel (can work or sleep in vehicle) increases miles traveled
- Provides convenient vehicle travel to non-drivers (e.g., youth, older adults, disabled populations)
- AV services increase amount of deadheading (zero occupancy) VMT
- Increases urban sprawl due to increased travel convenience

Estimated Range of AV Impacts on Energy Use

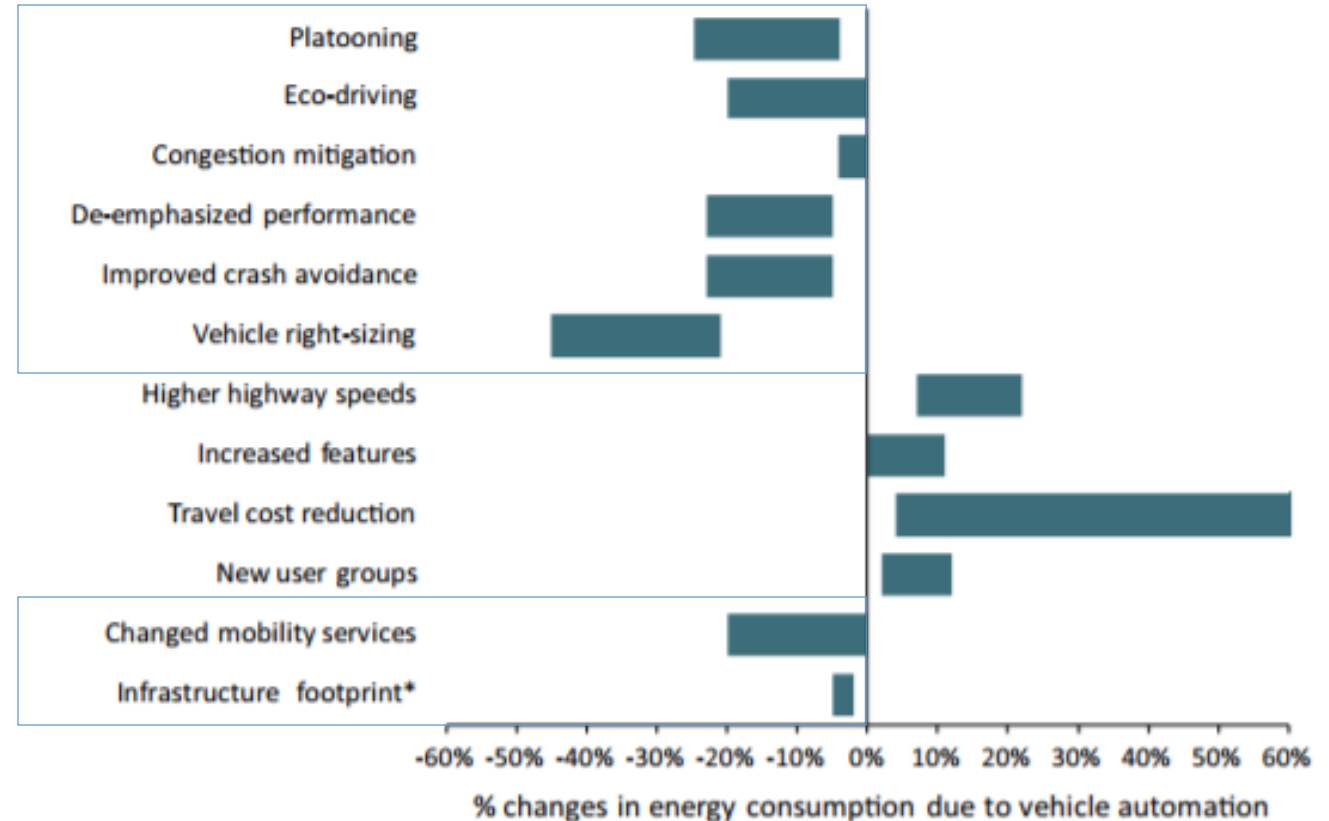


Source: Wadud et al., 2016

# SECA Potential Benefits

- Reduce GHG emissions and improve safety
- Increase capacity (smaller vehicles, closer spacing, shared rides, etc.)
- Reduce per mile cost (over privately-owned vehicles)
- Reduction in personal vehicle ownership due to uptake of shared AV services
- Automated public transit vehicles improve cost, quality, and desirability of public transit services
- Some reduced vehicle travel, such as looking for parking spaces
- Makes dense urban living more attractive due to reduced parking demand and pedestrian risks

Estimated Range of AV Impacts on Energy Use



Source: Wadud et al., 2016

# Passenger Rail

- Statewide **rail vision for 2040** is to increase the share of miles traveled via rail by **6.8 percent**
- Intercity rail lines will implement electrification technology
  - Local and regional rail may implement light rail and diesel-powered rail car technology
- Improved rail infrastructure will integrate with statewide high speed rail
  - Timed schedules will be necessary to fully integrate the rail system on local, regional, and statewide levels

Map of California High Speed Rail Plan





# Zero Emission Vehicles

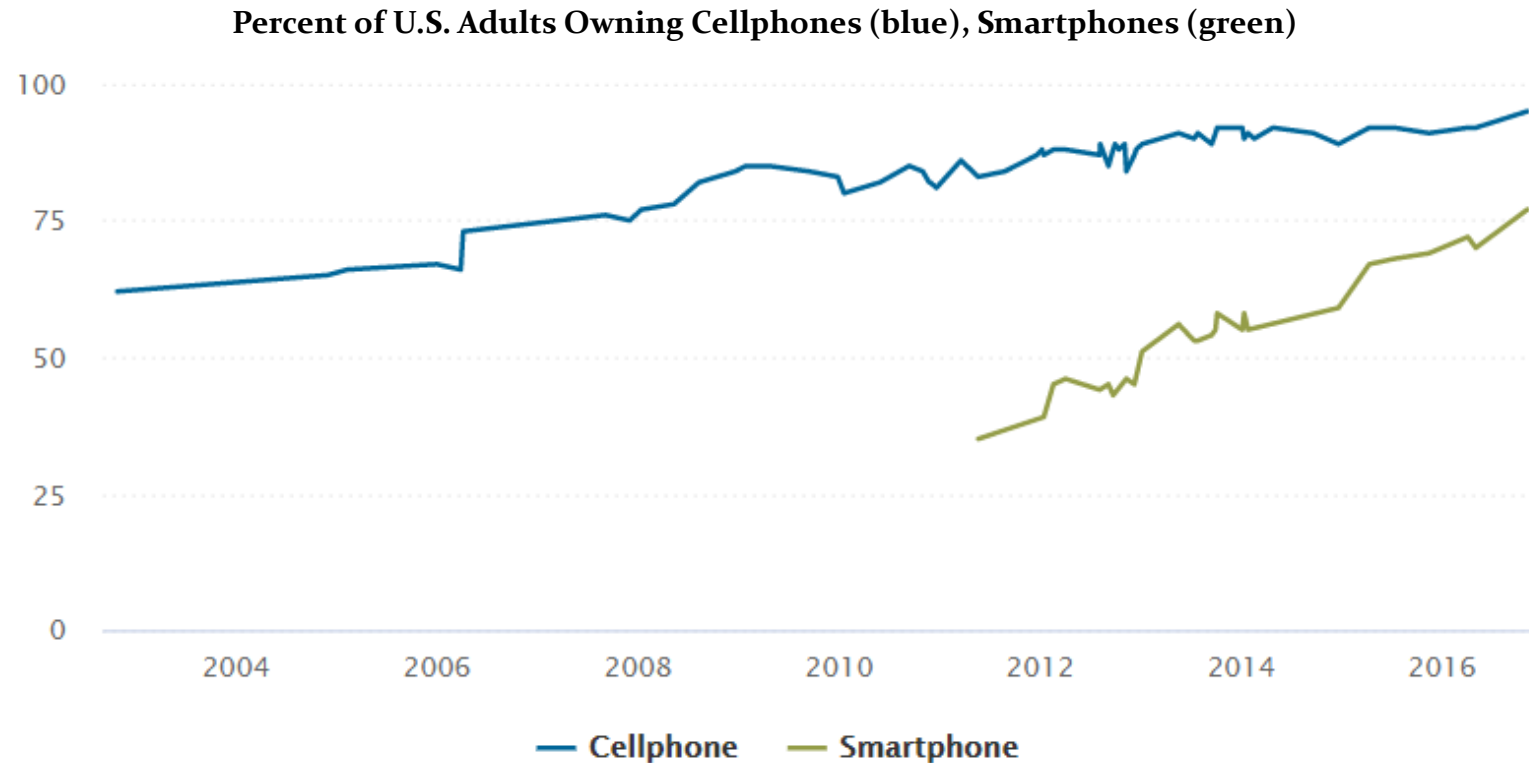


- Personal electric vehicle (EV) sales have grown at an increasing rate since 2013
- California's Zero Emission Vehicle (ZEV) Mandate includes increasing the number of ZEVs on the road by 1.5 million by 2025

## Variable ZEV Adoption Dates

<i>Description</i>	<i>Projected Date</i>	<i>Source</i>
2.9 million ZEVs on U.S. roads	2022	Rocky Mountain Institute, 2017
1.5 million ZEVs on California roads	2025	California ZEV Action Plan, 2016
EVs price competitive without subsidies	2025	Bloomberg New Energy Finance, 2017
95 percent of VMT will occur in shared EVs	2030	Airbib and Seabab, 2017
Pure EV sales overtake plug-in hybrid sales	2030	Bloomberg New Energy Finance, 2017
80 percent of shared AVs are electric	2040	Bloomberg New Energy Finance, 2017

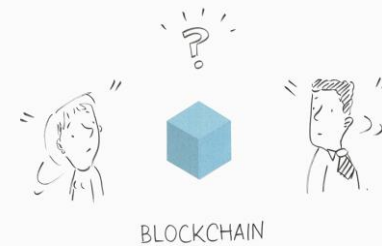
# Information and Communications Tech



Source: Pew, 2017

- GPS applications have revolutionized real-time and on-demand transportation services
- 5G is expected to be available for large-scale deployment in 2019
- 5G mobile and software networks could increase accuracy, flexibility of AV sensing technology

# Future Technologies: Cybersecurity, Freight & Blockchain



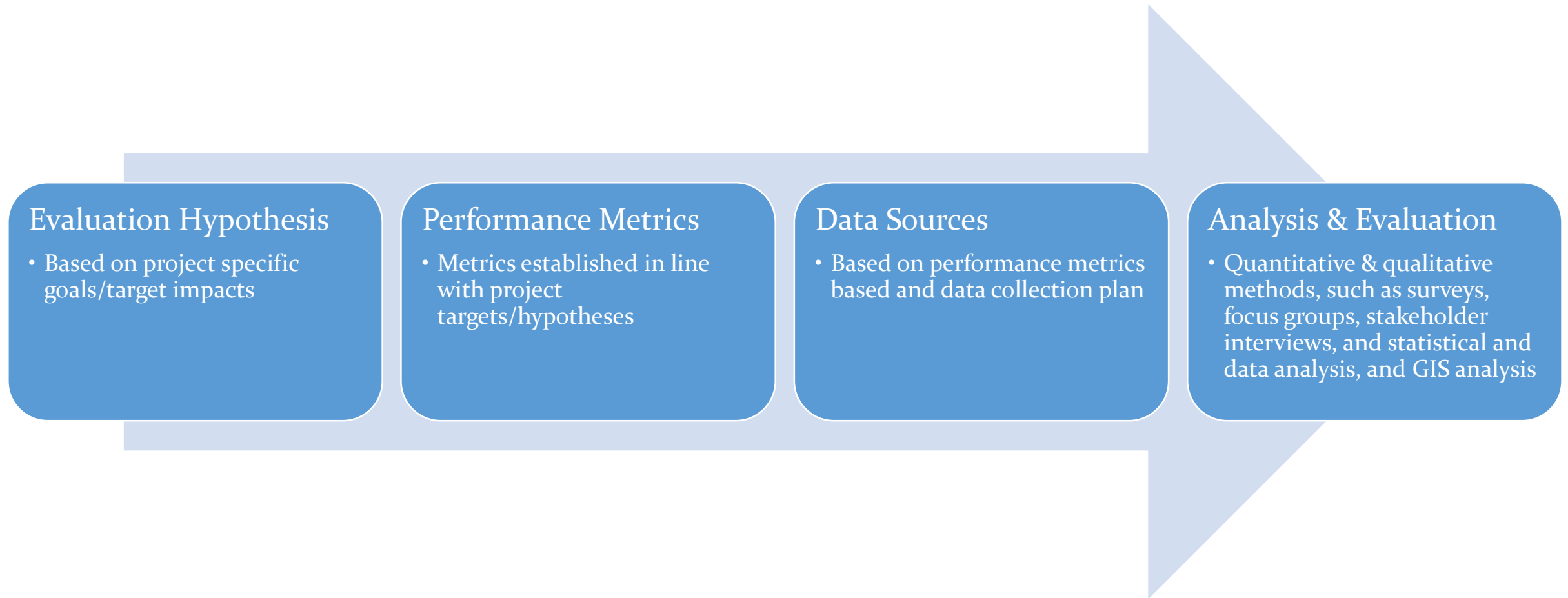
- Risk of **cybersecurity attacks** increasing with greater proportion of vehicles connected to wireless networks
  - Hackers could trick AI systems in AVs by altering physical environment as opposed to hacking vehicle systems themselves
  - Low-cost processors and updates may not include appropriate protection against cybersecurity attacks
- Rate of implementation of **3D printing, drones, “Uber for freight,” and hyperloop technologies** could affect last-mile goods movement by shortening supply chains
- Mobility data sharing via a **blockchain** could allow companies and individuals to share and monetize their own data with very low transaction costs in a secure marketplace
  - A blockchain-based carsharing network could allow for owners to rent their cars on a short-term basis at a potentially lower transaction cost than existing services

# Importance of Data and Research



- Need to develop data metrics, models, planning platforms, and methodologies to assess the economic and travel impacts of transportation innovations
- Longitudinal tracking and forecasting of modal impacts (temporal/spatial scale)
- Develop ability for public agencies to forecast the economic and travel behavior impacts of innovative pilot projects and guide public policy development
- Developing policies that balance data sharing with privacy (user, private companies, and public agencies)

# Evaluating Impacts of Pilots





# STEPS to Transportation Equity Framework



**SPATIAL EFFECTS**



**TEMPORAL**



**ECONOMIC**



**PHYSIOLOGICAL**



**SOCIAL**



# Modeling Future Scenarios

Modeling and scenario building should focus on the **direction and likeliness of future trends**, instead of precise measurements

- Public sector should remain aware of technologies that are seemingly far from widespread deployment



## FUTURE OF MOBILITY WHITE PAPER



# Concluding Thoughts



- Discussions of California's transportation future should include emerging topics
  - Research and analyses with specific measurements may be unavailable
  - Consider employing **directional trends** to support more **thorough analysis and planning**
- We need additional support to conduct **robust research efforts on future mobility**:
  - Understand the rate and degree to which technologies and services are expanding
  - Encourage **interdisciplinary collaboration**
  - **Synthesize** future projections and shifting priorities

# Innovative Mobility Highlights, Carsharing Outlook, and Latest Research

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**TECHNOLOGY**  
**NVIDIA and VW collaborate** to apply artificial intelligence technology to broader transportation challenges. The organizations had previously partnered to develop driverless vehicles and will continue to use machine learning applications for urban traffic flow optimization.

**RIDESOURCING**  
**Uber and Yandex combine their Russian ridesourcing business.** Both companies stated they would join forces in Russia, Armenia, Azerbaijan, Belarus, Georgia, and Kazakhstan to create a company that will operate in 127 cities. Russia's federal anti-monopoly regulatory body states the action would need approval as it potentially poses risk to competition.

**APPS**  
**TransLoc and Google announce partnership** to ensure accurate public transportation data are integrated into Google Maps. This partnership will allow TransLoc to manage larger volumes of real-time transit information for agencies and vastly improve access to public transit information for riders.

**PUBLIC TRANSIT**  
**Paris launches autonomous EV shuttle service pilot program.** Two companies, Navya and Keolis, are partnering with the Parisian government to offer the service free of charge. The shuttles carry up to 15 people each and will operate three different daily routes. The pilot will run until at least December of this year.

**BIKESHARING**  
**Seattle allows private bikesharing on city streets,** with as many as 10 companies planning to launch under the new program. Interested companies must roll out a minimum of 500 bikes and pay an operations fee to the city. This may lead to hundreds of thousands of dollars in public revenue. Helmet laws will still be enforced for users of the systems, but companies are not required to provide such helmets.

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innovative mobility

**INNOVATIVE MOBILITY: CARSHARING OUTLOOK**  
CARSHARING MARKET OVERVIEW, ANALYSIS, AND TRENDS • Winter 2018  
TRANSPORTATION SUSTAINABILITY RESEARCH CENTER - UNIVERSITY OF CALIFORNIA, BERKELEY  
By Susan Shaheen, Ph.D., Adam Cohen, and Mark Jaffee

doi:10.5072/F22M2Z2H5U

**Peer-to-Peer Carsharing Market Trends in North America**

Peer-to-peer (P2P) carsharing employs privately owned vehicles made temporarily available for shared use by an individual or members of a P2P carsharing network. Expenditures, such as insurance, are generally covered by the P2P operator during the access period. In exchange for providing the service, operators keep a portion of the usage fee. Members can access vehicles through a direct key or combination transfer from the owner or through operator-installed technology that enables "unattended access." Although P2P carsharing is more commonplace in the United Kingdom, Netherlands, Germany, and other parts of Europe, the market continues to grow steadily in North America. For instance, the P2P carsharing operator, Turo, expanded into Canada in April 2017, becoming the first American P2P operator to enter an international market.

As of January 2017, six P2P operators were active in North America and one in South America. Two more are planned for launch in North America. However, some operators reported ongoing legislative and insurance challenges, which pose barriers to expansion. TSMC researchers collected P2P carsharing data and fleet size / member estimates from the media, and primary sources from January 2016 through January 2017. As of January 1, 2017, a total of six P2P carsharing operators shared 131,336 vehicles with 2,904,180 members. Between January 2016 and January 2017, P2P carsharing membership increased 111%, and the number of P2P carsharing vehicles increased 80%. All P2P operators surveyed were for-profit operations. For more information on P2P service models, please refer to US Department of Transportation Primer (2016) *Shared Mobility: Current Practices and Guiding Principles*. See: <http://www.transportation.gov/SharedMobility>

P2P In North America (n=6)	Jan. 2016	Jul. 2016	Jan. 2017
Members	1,576,124	2,034,203	2,904,180
Vehicles	72,989	96,545	131,336

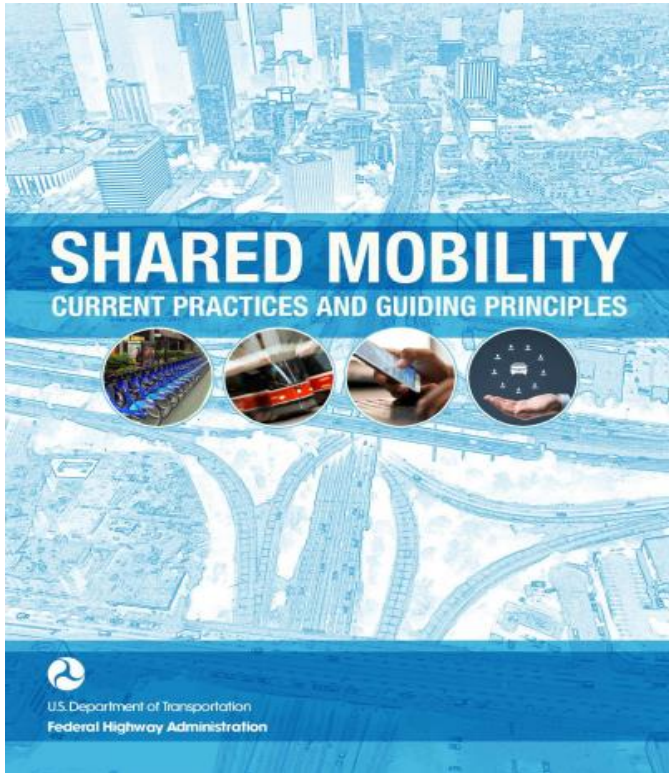
Note: provides via media were used for one out of six P2P operators in North America.

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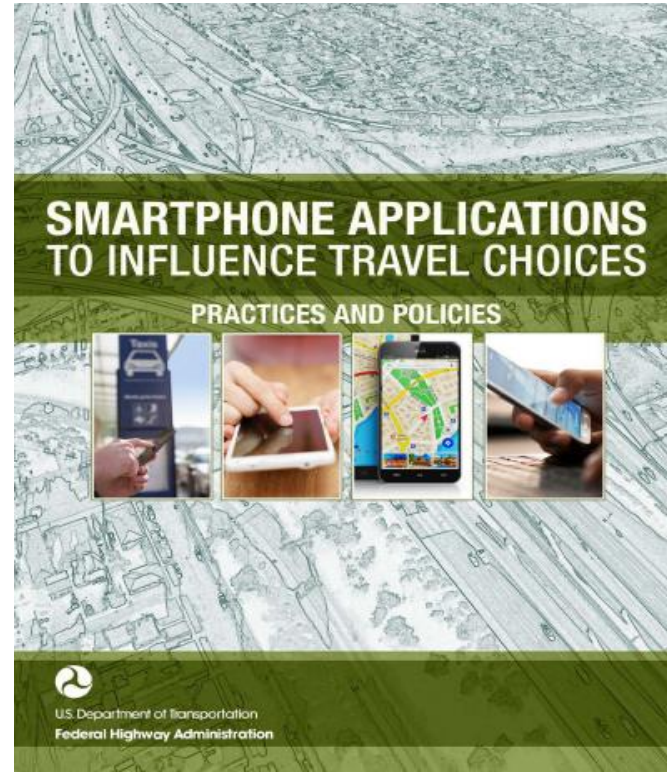
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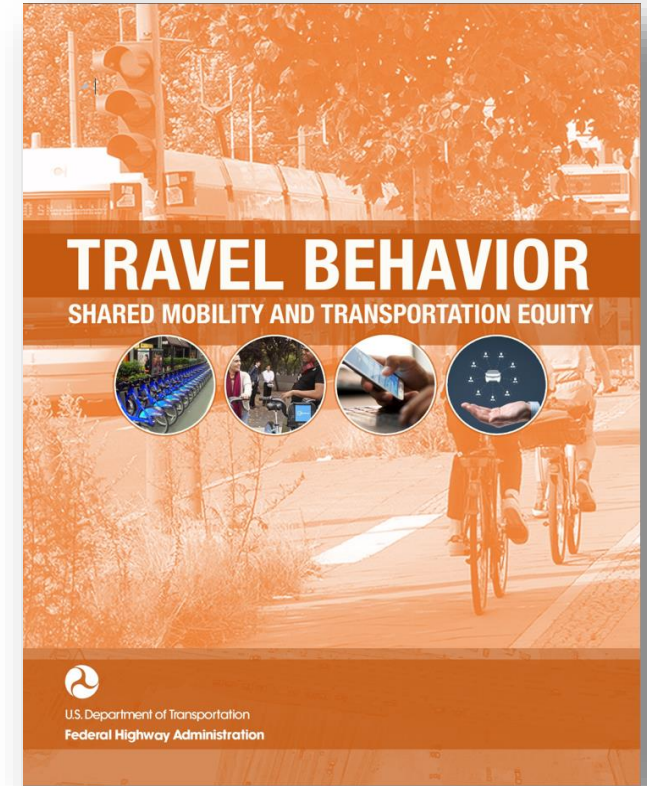
# US DOT Primers



<https://ops.fhwa.dot.gov/publications/fhwahop16022/fhwahop16022.pdf>



<https://ops.fhwa.dot.gov/publications/fhwahop16023/fhwahop16023.pdf>



[https://www.fhwa.dot.gov/policy/otps/shared\\_use\\_mobility\\_equity\\_final.pdf](https://www.fhwa.dot.gov/policy/otps/shared_use_mobility_equity_final.pdf)



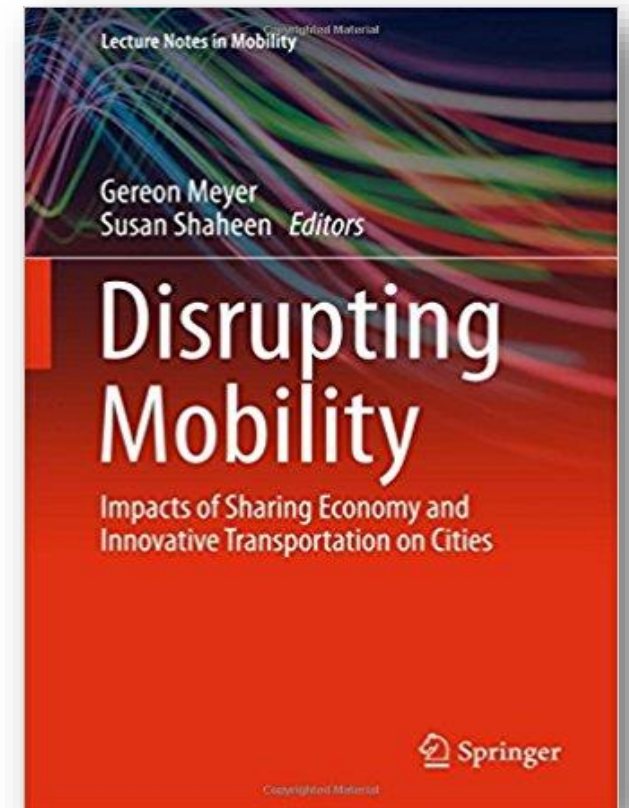
# Recent Resources



<https://escholarship.org/uc/item/68g2h1qv>



<https://rosap.ntl.bts.gov/view/dot/34258>



<https://www.amazon.com/Disrupting-Mobility-Impacts-Innovative-Transportation/dp/3319516019>

# Acknowledgements

- California Department of Transportation: Gabriel Corley, Patrick Record, Tyler Monson
- Shared mobility operators, experts, and industry associations
- Federal Highway Administration
- Mineta Transportation Institute, San Jose State University
- American Planning Association
- Adam Cohen, Rachel Finson, Elliot Martin, Adam Stocker, Hannah Totte, Mark Jaffee, Marcel Moran, Mikela Hoffman-Stapleton, TSRC, UC Berkeley



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